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BUREAU OF FISHERIES

HENRY O'MALLEY, Commissioner

PROPAGATION OF PONDFISHES

By M. C. JAMES

U. S. Bureau of Fisheries

APPENDIX II TO THE REPORT OF THE U. S. COMMISSIONER
OF FISHERIES FOR 1929



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PROPAGATION OF PONDFISHES ¹

By M. C. JAMES,² *U. S. Bureau of Fisheries*

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INTRODUCTION

The propagation of fish ³ on farms in artificially constructed ponds or in natural ponds of limited area is perfectly feasible, and with proper management such ponds will afford a convenient and economical food supply that will justify the expense of their construction or preparation and maintenance. The interest exhibited by sportsmen's organizations in rearing game fish for stocking public waters also makes it desirable to emphasize the possibilities inherent in lands frequently unsuited for any purpose other than fish culture. Areas otherwise unproductive except by recourse to expensive drainage operations may be made to provide material returns as a source of food and game fish.

It is the purpose of this report to point out briefly the essential features to be considered in the location of a site, the construction of the pond and its operation, and the care of the fish contained therein.

This information has reference exclusively to the rearing of the spiny-rayed or warm-water fishes, which are especially adapted to culture in ponds, and which can not be propagated by the artificial methods applicable to the trouts and salmons.

¹ Appendix II to the Report of the U. S. Commissioner of Fisheries for 1929. B. F. Doc. No. 1056.

² This document is a revision of Bureau of Fisheries Document No. 826, Fish Ponds on Farms, by Robert S. Johnson and M. F. Stapleton, which was Appendix II to the Report of the U. S. Commissioner of Fisheries for 1915 and was issued on December 15, 1915.

³ This document covers the propagation of the basses, sunfish, and catfish only. Information concerning the propagation of carp, buffalo fish, trout and salmon, shad, whitefish, grayling, lake trout, pike perch, and yellow perch is obtainable from other publications on sale by the Superintendent of Documents, Government Printing Office, Washington, D. C. Information concerning these other forms will be furnished upon application to the Bureau of Fisheries, Washington, D. C.

It is not purposed to discuss minor technical details applicable only to the hatcheries conducted by the State and Federal Governments. The object is rather to outline in a broad way the methods whereby the culture of fish can be carried on as an adjunct to farming or as an activity of groups of sportsmen.

COMMERCIAL VALUE OF POND FISHES

The value of fish in the human diet is so well attested by an impressive array of data that it is unnecessary to dwell upon this phase here. In spite of recent improvements in the marketing of fish, permitting delivery of the frozen product far from the point of catching, there are many sections of the country that are not able to enjoy a regular supply of fresh fish in any form. Fortunately, such areas frequently furnish exceptional facilities for the construction of farm fishponds and the occasional supply of fresh fish thus obtained is highly welcome. Many correspondents intimate that there would be a ready local sale for fish so raised in the semiarid regions, and there is likewise a fairly steady demand for bass and bluegill sunfish for stocking purposes. Prices vary, but fingerling bass generally sell at from \$20 per thousand upward, according to size, while the sunfish and other varieties command a lower price.

The bureau is in frequent receipt of requests for an opinion as to the monetary profit to be reasonably expected from a commercial hatchery for pondfish. The bureau is unable to offer any suggestions on this point as there are no authentic published records of financial returns that may be expected from the pursuit of pondfish culture on a commercial basis. Many theories have been advanced on this point, but, as in other undertakings of importance, the efficiency necessary in order to conduct such a business profitably can be gained only by repeated efforts and actual experience. Furthermore, in order to arrive at an estimate of any value one would have to take into consideration such important factors as the topographical features of the site, the character and quantity of the water supply available, the extent of the enterprise, and the location of the plant with reference to market and transportation facilities. Taking all these facts into consideration, one can readily see the futility of attempting to forecast in a general treatise the financial returns that may be expected from any given pond area devoted to commercial fish culture.

All this, however, detracts in no way from the argument favoring the construction of ponds with the view to providing a food supply for private use. The feasibility of pondfish culture on this basis has been demonstrated fully, and ample quantities of fish for home use are to-day being propagated in established ponds on farms, proving the value of such an undertaking for that purpose alone.

With regard to the rearing of the game varieties for angling, it is generally true that sportsmen can propagate the bass, sunfish, crappie, and similar fish at less cost than purchasing them and, furthermore, can be assured of a supply when State and Federal hatcheries are unable to furnish them, as is frequently the case.

UTILIZATION OF WASTE LANDS

The bureau aims especially to influence the utilization of the natural and favorable water areas existing on countless farms, which at the present time are being put to no use, many of them constituting unsightly waste spaces that detract from the value of the land. The presence of springs, lakes, flowing wells, or adjacent streams are all leading incentives to a fishery project, and suitable sites for the construction of ponds, especially if at present unremunerative, should make their use for such a purpose desirable to the thrifty husbandman after a full comprehension of their possibilities in a fish-cultural way.

Ponds intended primarily for the cultivation of fish may be conveniently located for the watering of stock, or the overflow therefrom may be utilized for the irrigation of land. In many sections of the United States artificial ponds on farms are an absolute necessity to serve one or both these latter purposes, and by a merely nominal expenditure such water areas may be utilized advantageously for the growing of fish without interfering in any way with the original uses for which they were intended.

There are many cases in which the drainage of marshy or flooded areas would not return an income commensurate with the cost of the work, and in such instances the lands might be made productive by utilizing them for the production of fish or fur-bearing animals.

At the outset the main object of the amateur farmer fish-culturist should be the production of a food supply for home consumption.

After gaining the required experience and knowledge of the subject as a result of conducting work for several years on a limited scale, the farmer will be well qualified to judge as to the practicability of extending his operations and can then, if he so chooses, increase his facilities with the view of raising fish for the market.

Frequent inquiries are received by the Bureau of Fisheries regarding the use of natural ponds, lakes, and streams for the raising of fish. With respect to such water areas it may be stated that if drainage is provided for, the pond bed cleared of débris, the site protected against the inflow of surface water—if, in short, complete control is affected—natural water areas will possess many advantages over artificial constructions. There is objection, however, to any body of water not under complete control.

WATER SUPPLY—VOLUME, QUALITY, AND TEMPERATURE

In a brood pond a constant water level should be maintained at all times, especially during the breeding season. The required flow, which will vary with the character of the soil, must be sufficient to replace loss by evaporation and seepage. An amount just short of overflowing the pond is the ideal to be attained, as it is desirable to avoid a current. A surplus of water is preferable to a shortage, as any excess may be easily diverted through waste channels or held as an emergency reserve.

For a 1-acre pond, where the sides and bottom are of clay or rich loam, a flow of from 30 to 50 gallons per minute should be sufficient

to maintain a proper water level at all times, while sandy or gravel soil untreated may require double that amount. A practical method of measuring the flow of water from any source is as follows:

Select a stretch on the stream or ditch affording as straight and uniform a course as possible. If the water at any point is carried in a flume, it will be better to measure at that point. Lay off a distance of, say, from 10 to 50 feet; measure the width of flowing water at about six different places in this distance and obtain its average width. Likewise, at these same points measure the depth of water at three or four places across the stream and obtain its average depth. Then drop a float in the water and note the number of seconds it takes to traverse the given distance. The product obtained by multiplying the average width in feet by the average depth in feet by the velocity (expressed in number of feet per second) will give the flow of the stream in cubic feet per second. From the figures so obtained it is advisable to deduct about 20 per cent, as the surface velocity of water is in excess of the actual average velocity.

High temperatures in season are necessary in brood and rearing ponds. If the water is cold at the source, the fault must be corrected by reducing the inflow to the lowest quantity that will maintain a uniform level, thus allowing the maximum absorption of warmth from the sun and air. Water that does not fall below 60° F. in the brood pond during the spawning season is desirable.

SOURCES OF WATER SUPPLY FOR PONDS

Springs are the most dependable of all the sources of water supply, requiring the minimum expenditure in preparation and being the least subject to outside influence. The presence of injurious mineral substances usually can be detected without expert analysis, but the amateur fish-culturist may be surprised to learn that so-called pure water often carries abnormal proportions of oxygen or nitrogen gases in quantities inimical to fish life. This may be due either to subaeration or supraeration, and the results following the use of such water will be as disastrous in the one case as in the other.

This contingency and the requisite of high temperature make precarious the embodiment of springs and wells within the pond bed. In the absence of thoroughly demonstrated fitness, the more prudent course will be to provide an independent water-supply reservoir, apportioning its area to the volume of the spring. While being held in this reservoir the gaseous contents of the water will be corrected and its temperature seasonably modified.

The flow from many springs is so obstructed through the trampling of stock or from other causes that they emit only a small portion of the water available near the surface. In such cases the supply usually may be increased materially by sinking 2-foot lengths of terra-cotta pipe over the bubble and removing the incased earth. Several such pipes in a promising area often will result in an astonishing increase in flow. Where the cost is not prohibitive, however, the better course will be to excavate the site and wall it in with rock and concrete.

In profusely watered sections—notably in the States bordering the Great Lakes—there are many tracts of marshy characteristics, some

of them hundreds of acres in extent, promiscuously interlaced with tiny rivulets that combine to form streams of considerable size. Seemingly inexhaustible quantities of water lie close to the surface in many such places, and by driving pipes only a few feet into the ground flowing wells are obtained.

Where the volume of water is a matter of concern the overflow level of spring reservoirs, sunken tiling, or driven pipes should be kept as low as possible consistent with the object in view, as the flow will naturally decrease with the elevation of the head against which it works.

A broad pond contiguous to a spring reservoir may be fed through a spillway directly into the stock pond. Where a reservoir is impracticable, at least partial correction of any abnormal condition of the water may be brought about by conducting it to the pond through open ditches or raceways of wood or concrete, the choice of material being determined by adaptability of the soil and the comparative expenditure involved.

The chief objection to creek or river water as a supply for fishponds is the great quantity of mud and débris carried during freshets and the excessive cost of effective measures to prevent its introduction into the ponds. Streams subject to extremely high water are totally impracticable as a source of supply, while those of lesser floods can be utilized only after a considerable initial expenditure, and much vigilance will be entailed in their use, as large and continuous deposits of mud in breeding ponds will ruin any eggs present and invariably kill recently hatched fry. Furthermore, protracted roily water will retard and sometimes prevent growth of the aquatic vegetation so essential to pond fish-cultural operations. It is also imperative that undesirable and predacious fishes be rigorously excluded from the ponds, and it will be impossible to accomplish this if the water supply is beyond control during certain periods.

From the foregoing it can readily be seen that if a stream is subject to appreciable changes as a result of storms or drainage from local watersheds it will be unwise to establish a pond therein by the construction of dams, as is often contemplated. It will be entirely feasible, however, to conduct water from such a stream to ponds adjacently located, provided the intake is adequately screened, the supply arranged so that it can be cut off during times of excessive turbidity, and measures are taken to prevent the inundation of the pond site in high-water periods.

It may be necessary to erect a dam in the channel of the stream to provide the required head of water for a gravity flow to the pond, in which case it may be of a simple type designed merely to accomplish the end in view. The intake from the stream should be wide and deep, thus presenting a large screen surface to obviate the complete stoppage of the water supply in the absence of the caretaker. It should be covered by a series of screens graduated in size, the first to consist of coarse hog wire, or wooden racks with like openings, to catch the largest objects. The intermediate screen (of 2-inch mesh) will intercept vegetation, while the inner one must be fine enough to exclude smaller débris and the fry of undesirable fishes. Immediately below the screens, gates should be provided so that the water

may be shut off at will and diverted into a storm channel when it becomes too roily for use.

Where the source of supply is a lake the difficulties referred to above are not encountered, lake water seldom being roily and demanding less attention to screens owing to absence of currents.

Uncontaminated open waters have many advantages. Their temperatures are seasonal; usually there are no abnormal gaseous constituents to be corrected; the plankton or pelagic animal and plant life contained therein forms a valuable addition to the natural food supply in the pond; and were it not for the difficulty of control and occasional roiliness, such waters would be preferable to springs and wells as a source of supply to fishponds.

Wells, both flowing and power lifted, are successfully used in some sections for the cultivation of fish. Before incurring the expense of constructing ponds to be supplied from such a source, however, it will be advisable to test the water thoroughly in order to demonstrate its fitness for fish culture. This can be done best by fitting up a running-water supply in a retaining reservoir and holding therein, for an extended period, a number of specimens of the species of fish it is desired to propagate. If they thrive, it may be assumed that the water is free from injurious gases or mineral substances and is adapted to the work it is proposed to undertake.

RAIN WATER (SURFACE DRAINAGE).—Another class of ponds available for the propagation of fish, known as "sky ponds," embraces those wholly or partly dependent upon local precipitation for their supply of water. Such ponds are invariably profuse in the production of fish food, and for this reason would be ideal were there an auxiliary water supply adequate to maintain constant surface levels during the critical nesting season and a fair depth throughout the remainder of the year. In the absence of this reserve many such ponds become virtually dry during periods of drought or freeze to the bottom in the winter months. Where ponds are subjected to such conditions fish-cultural operations are impracticable.

Ponds dependent entirely upon precipitation and surface drainage for their water supply must necessarily be located at a low elevation in order that the surface drainage from surrounding lands may be taken advantage of. Land depressions, ravines protected from floods, or swamp lands are desirable sites for such ponds.

Catfishes only can be recommended for the best of "sky ponds," strictly speaking, and the results even with them will be very uncertain.

DESIRABLE SITES FOR THE LOCATION OF PONDS

If a gravity flow of water is contemplated, the fishpond must, of course, be located below the level of the source of supply. Porous soils are to be avoided, if possible, not only because of the large volume of water required to replace loss from seepage but because they are usually sterile. Swamp lands, old watercourses, and catch basins of years' standing are the best and most productive soils as they possess the required fertility and contain seeds and spores for the early development of profuse vegetation and animalcula. Ponds located in such soil will maintain their water levels with a minimum inflow.

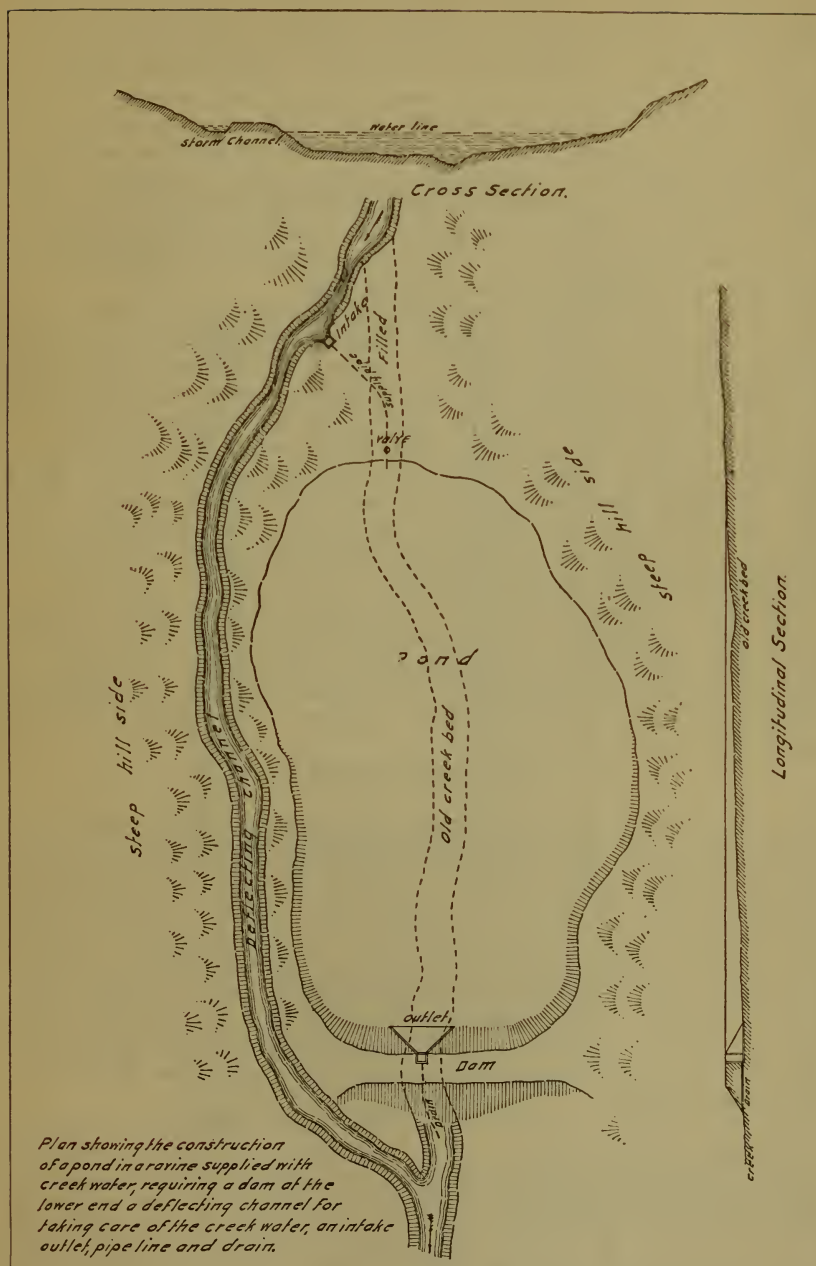


FIGURE 1

Satisfaction may be had from ponds less favorably located, however, if good sense is employed in their preparation and maintenance. Aside from the ideal lands of alluvial deposits, clay loams are a first choice, being most nearly impervious to water and quickly responsive to efforts made to establish their fertility. Sandy loam, being the most prevalent, is probably the most general soil in use for pond construction. While some difficulty may at first be experienced in making it retain water, this is overcome in time by the accumulation of decayed vegetation. Its fertility is good, and, in general, it produces a sufficient supply of natural food. Even clear sand and gravel mixtures may be made to hold water and brought to fair productivity by increased expenditures in construction and by the application of fertilizers in a manner to be explained later.

It is very desirable and also essential for a marked degree of success that ponds be so located and constructed that they may be entirely emptied of water at certain seasons. To this end there should be accessible a natural dry run or watercourse lower than the bottom of the proposed pond, to which drain pipes may be conducted.

Ponds are drained for the purpose of assorting fish, removing objectionable species, reducing the stock, and killing excessive vegetation. Complete drainage can not be effected, of course, unless there are adjacent waters to which the fish can be removed during this process. A number of small auxiliary ponds will always be found advantageous in fish-cultural work.

Where the primary purpose is other than fish culture, the selection of the site must depend upon the more important object in view. Fish culture will yield very satisfactory returns as a secondary enterprise, but the site selected for the work should by all means be the best available consistent with the general scheme of farming operations.

POND CONSTRUCTION

The exact mode of construction must depend largely upon local conditions, such as the presence or absence of favorable land contour, the nature of the soil, proximity to storm channels, and the area of the ground to be worked. Even with these features specified, lesser local characteristics and the exigencies of individual circumstances will vary the application of any approved general method. Where practicable, ponds should be not less than 1 acre in surface area. Those of smaller extent will produce fish and add an interesting feature to farm life, but they will not yield adult food fishes of the larger species in quantities sufficient for the requirement of the average farmer's table.

Natural draws or ravines involve the least expenditure in their adaptation to fishponds, as two and frequently three sides are already formed, so that an earthen embankment connecting them will complete the inclosure. Such locations must be surrounded by ditches to divert surface water where that is likely to roil the pond, and effective waste channels should be provided if the site covers the natural course of flood waters.

If flat land of an elevation only slightly lower than that of the source of water supply is selected, it will be necessary to excavate the ponds in whole or in part to the required depth to insure a water

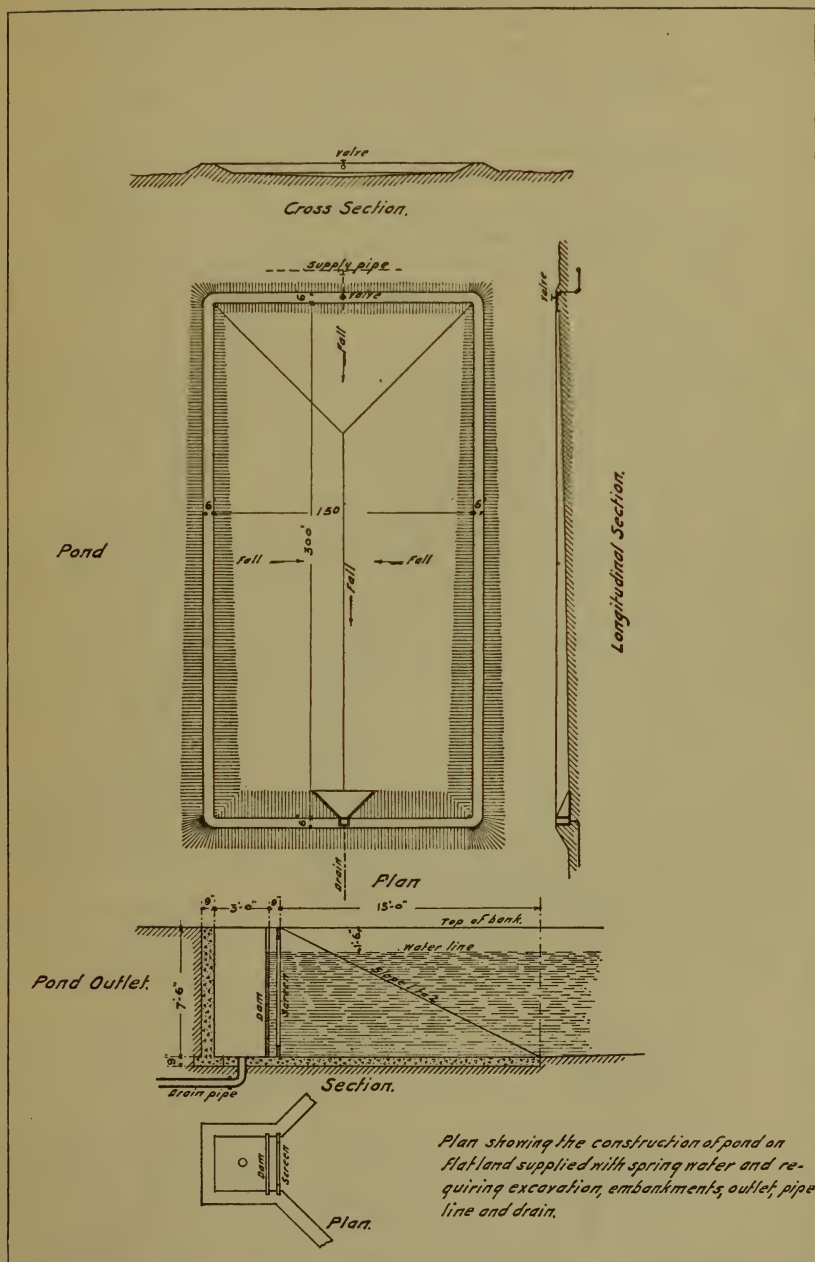


FIGURE 2

level lower than the supply. Thus the excavations will form solid banks, which, if impervious to water and properly sloped, will require no further attention except to bring them to uniform widths and elevation, which can be done with the material excavated in forming the pond proper. The bottom of the pond should be shaped to drain to a central point.

On swamp lands and depressions which are susceptible to drainage and are at the same time low enough to insure a gravity flow of water from the source of supply, one or more fishponds can be constructed by the erection of longitudinal and cross-section dikes high enough to provide the required depth of water. The construction of such ponds involves only sufficient excavating to give the bottom the proper slope. In other words, the pond should be built up rather than excavated, and the water level therein will be higher than the surrounding land.

The method of constructing pond embankments is governed by the topography of the land, the character of the soil, and the volume and pressure of the water to be confined. All made embankments should be at least 6 feet wide at the top and the sides sloped not less than 2 feet to each foot in height. For instance, a 6-foot fill should be 30 feet wide at the base and 6 feet at the top.

Prepare the foundation by plowing the site of the embankment, after first removing all trees, underbrush, rock, and sod, and, as an extra precaution against seepage, dig a trench 12 inches deep along the median line. This will form a break or set-off between the original ground and the made construction, which is a point of natural weakness. The filling should progress by layers over the full width and length of the levee as a continuous operation rather than by sections; otherwise the completed work will later develop checks by reason of variations in material and compactness. Rocks are of use as a protecting riprap on the slopes after completion.

In case the water supply to a pond is taken from a creek, the latter must be dammed and an intake built above the construction provided with screen and dam boards, from which a water conduit must be laid to the pond. The dam should be provided with an ample spillway, which may best be constructed of concrete.

The shape or outline of the pond is immaterial. Currents of water are undesirable in the propagation of the spiny-rayed fishes. In fact, the best brood and rearing ponds are those which are supplied by backwater from other bodies, and if there is reasonable depth and a fair growth of vegetation no stagnation will result.

Success in pondfish culture is being attained with widely varying forms of construction. To a considerable extent fish will adapt themselves to existing physical conditions. In nature they seek comparatively shoal waters in which to spawn, by reason of the prevailing higher temperatures, and during certain stages of their growth the young choose similar depths, where food is plentiful and beyond the bounds of the customary range of large fish. Relatively deep waters must be accessible to the stock fish during winter months, and what this depth shall be will depend largely upon the latitude of the location; cold climates where great thickness of ice forms require the deepest pools.

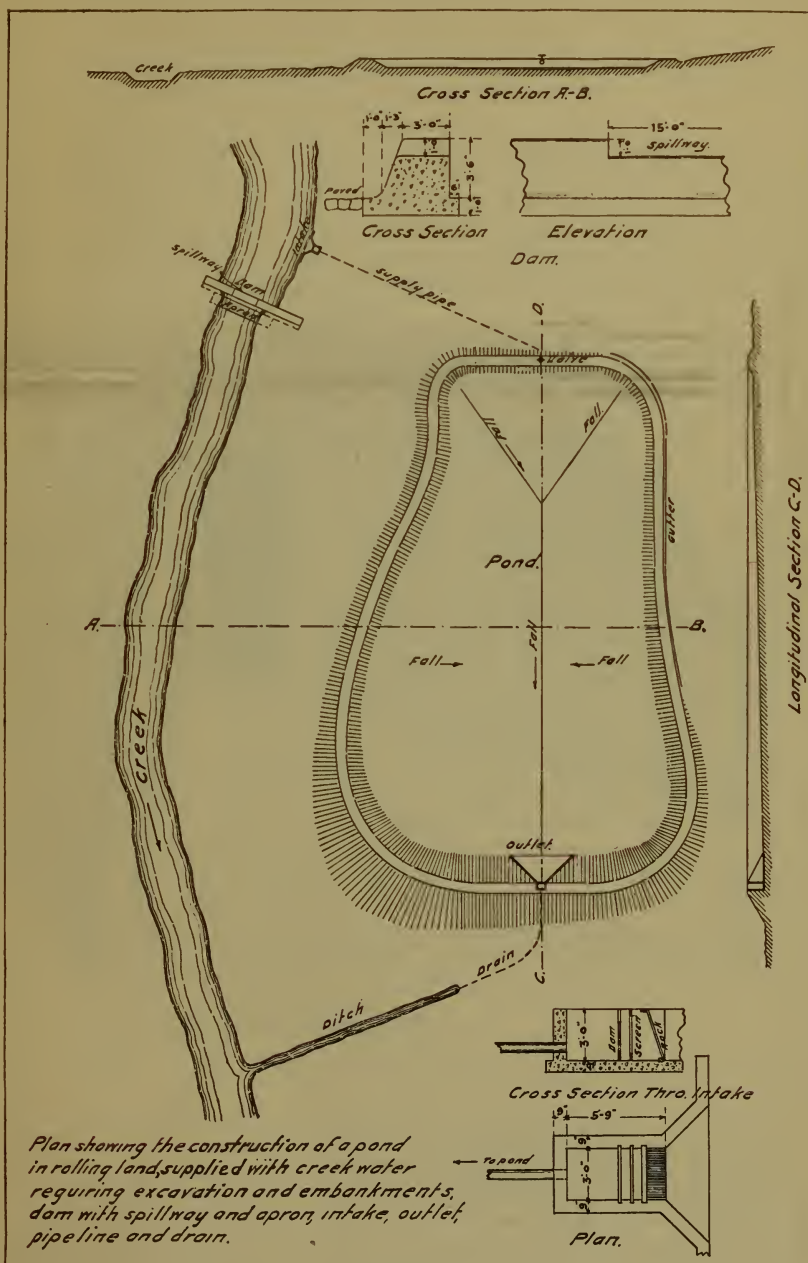
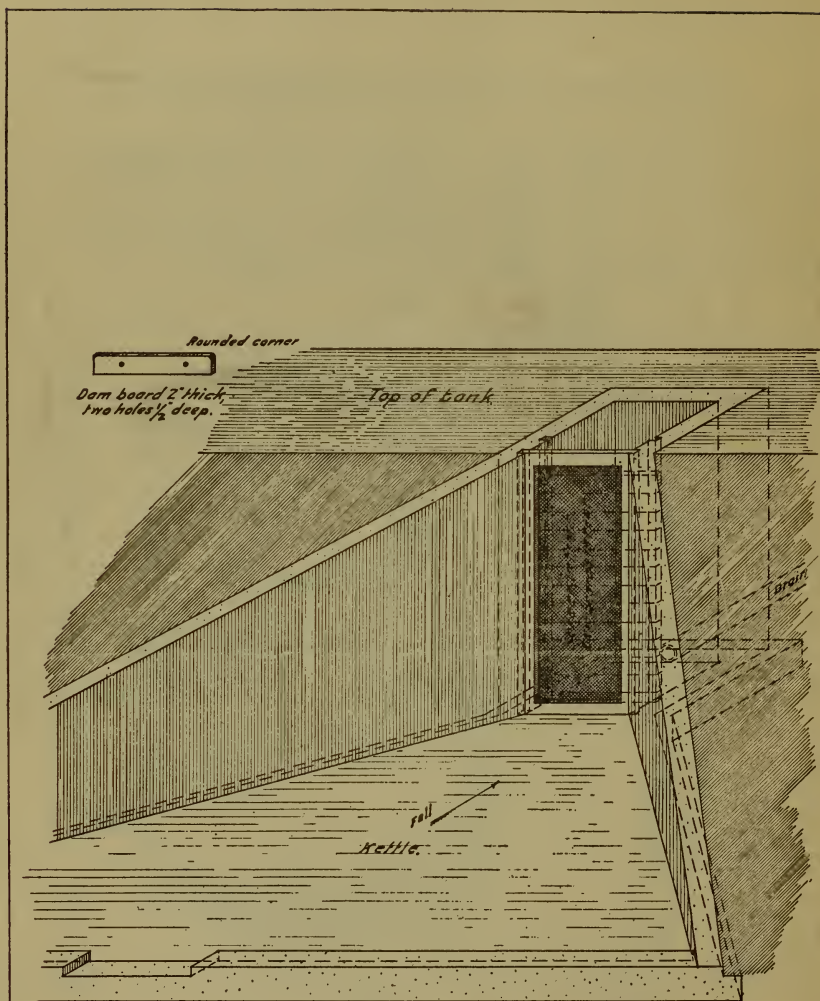


FIGURE 3



Pond Outlet of Cement.

Outlet made of wood is similar in construction to that of concrete, requiring driven posts under same to secure it and suitable cleats to hold screen and dam boards.

FIGURE 4

Experience teaches that breeding ponds should be excavated to hold not less than 12 inches of water at or near the margins; that one-fourth of the pond area should range from 12 to 30 inches in depth; and that one-half its total area should be not over 3 feet deep, the bottom of the remainder to slope from this depth to 6 feet or more at the outlet. Avoid abrupt slopes. Provide complete drainage to the deepest point, where a waste pipe controlled by gates or slash boards should lead to outside natural channels.

It will be found a great convenience when draining ponds to have shallow channels 6 inches deep and 15 inches wide at the head of the drainpipe, radiating to all parts of the pond bottom from a kettle or pit, which may be of wood or concrete. A large percentage of the fish will follow such channels as the water recedes and may be removed from the kettle with less danger of injury than if picked up promiscuously about the pond.

Remove all projections from the pond bottom that might interfere with the operations of seines; plow the entire bed and level it with harrows before turning in the water or treating further for water-tightness.

As stated above, ponds located on swamp bottoms or in clay soils are virtually impervious to seepage, and there should be no difficulty in maintaining their surface levels. Sandy loams are more uncertain; they require time to become thoroughly saturated but will improve in this respect from year to year through the accumulating deposits of decaying vegetation. It is an excellent practice, when first filling newly constructed ponds with water, whatever the nature of the soil, to follow the advancing water line with a drag or harrow, driving the team knee-deep into the water. The constant roiling and puddling of the ground in this manner is very effective in cementing open cracks and crevices. Very porous soils may require the addition of a layer of clay before they will hold water. From 2 to 6 inches of stiff brick clay over the entire bottom and up the sides, well above the water line, the bottom harrowed down as explained above, will hold water over the most open ground likely to be used. The only objection to the presence of clay is its general sterility, but this may be corrected by another layer of rich loam, after the clay has been worked down and proved efficacious. Where this process is to be employed allowance must be made at the time of excavation for the refill of 12 or more inches. Coarse stable manure, and even clean straw, well trampled into the pond bottom, has been reported as a successful remedy for seepage.

A good set of native sod or sedge grass around the entire pond at the water line is the best preventive of wave washing and encroachments upon new fills. If the location is such that strong currents or eddies are present, piling, rock riprap, or other reinforcement will be necessary at the points of greatest exposure.

Landowners desiring to undertake fish propagation may feel that the expenditure necessary to secure completed ponds, as described above, is prohibitive; or they may have waters available for fish culture that it would not be expedient to remodel along the lines indicated. The plans outlined are in accordance with the present-day standards. Fish may and are being propagated successfully in

far less ideal environments, but in such cases more native ingenuity is required. This, however, is a common attribute of the American farmer, and anyone who can mix balanced feeds, practice scientific grain breeding, or master the intricacies of modern farm machinery need not hesitate for fear of failure to add fish culture to his daily routine.

Summarizing the construction, these features should be provided for:

1. Water-tightness, so that a small inflow will be sufficient. This will result in high temperatures during the summer months.
2. A shallow area, from 18 to 30 inches deep, where the fish may nest.
3. A deeper area, of 6 feet or more, for winter quarters. This will also be occupied by the adults in the summer, after nesting is completed.
4. A fertile bottom for the growth of aquatic plants, upon which fish food depends.

If these requisites, together with a suitable water supply, are provided the fish will thrive.

The accompanying drawings explain the types of intake and drainage devices that have proved effective. These may be varied to meet the conditions encountered and be constructed of either wood or concrete. The latter material is shown in the illustrations and is the most durable, but wood will be equally as satisfactory while it lasts.

While the type of pond outlet illustrated is probably the cheapest and most satisfactory, variations may be employed with equal success. Where it is not practical to locate the drainage outlet immediately contiguous to the pond embankment, a standpipe outlet may be constructed at the lowest point in the pond. This is merely a chimney-shaped structure of cement with one side open. Provision is made for slots to retain dam boards and a screen on the open face. The outlet should be 3 or 4 feet square, and the top should be 6 or 8 inches above the highest water level. It is connected at the base with a tile outlet pipe conducted through the pond embankment to discharge in a ditch. To facilitate rapid drainage the tile should be of 10 or 12 inch diameter. The same result may be gained by utilizing an upright piece of large-diameter iron pipe for a standpipe. The base is attached to the drain line by a loosely threaded elbow. The height of water in the pond can thus be regulated by swinging the upright pipe at an angle and holding it by attachment to stanchions constructed for the purpose. A hemispherical screen covers the top of the standpipe. However, such an arrangement is undesirable in cold climates or where floating algæ or débris may clog the small screen surface.

AQUATIC PLANTS AND THEIR VALUE IN POND FISH CULTURE

Frequent reference has been made to the necessity of vegetation in fishponds. Its advantages are many. It serves as food and a harbor for the lowest forms of minute animal life. Each advance in the scale of life constitutes a food for higher forms, and in the guise of fish the fertility of the ground contributes to the food of the human race.

Plants play an important part in the purification of water, taking up the carbonic acid gas liberated by decomposition and liberating the oxygen essential to living creatures. They thus prevent the asphyxiation of fish life and act as a corrective of many abnormal characteristics of individual waters.

Losses of fish through the depredations of enemies will be greatly lessened where there is an abundant aquatic growth in which they may hide. It furnishes a grateful shade on bright warm days, and the interlacing roots so bind the bottom soil as to prevent turbidity from casual disturbances.

The aquatic flora of a locality varies greatly with its latitude and is also governed by the chemical ingredients of specific waters. The most desirable species usually thrive best in waters of limestone origin. Plants of filamentous character are preferable to the large spatulate-leaved kinds, as they present greater surface expanse for the exchange of gases and, on account of their shallow rootage, are more readily controlled by the fish-culturist. Pond lilies, cat's-tail, and coarse water grasses or weeds in moderation are beneficial, as they afford shade and shelter. However, they are lower forms of oxygenators than the plants of finer growth, and they make seining operations more difficult; and it is virtually impossible to eradicate them after they have obtained a foothold.

All species herein described that are indigenous to the waters of the locality in question may be utilized advantageously in pondfish culture. Undoubtedly one or two of the introduced species eventually will drive out the others, but those remaining will be the ones best adapted to the environment. All of these will grow from cuttings, making it unnecessary to transplant the roots. The plants may simply be raked or pulled out of the open waters and pressed by handfuls into the soft earth in the shallow sections of the new pond in spaces about 5 feet apart. The bottom must be covered with 6 to 12 inches of water during the operation, otherwise the sun and air will soon ruin the sets. In deep water the plants may be started by attaching a weight and sinking them to the bottom of the pond.

Much time and trouble are often required to bring about a profuse growth of aquatic vegetation,⁴ but after a pond is thoroughly stocked even more labor is required to keep it within bounds. Ponds may become literally choked with water mosses, resulting in inconvenience to the owner and a detriment to the fish. They will roll the seines, snag the lines, and smother the fish when an attempt is made to draw down the water. It will usually be necessary to thin the moss out once or twice in the course of a summer, and all growth should be removed when draining the pond. An efficient method of removal is by raking, the worker standing on the embankment and throwing the moss out on land, or wading into the shallow water of the pond, drawing it from a circle about him, and building cocks of it. The deeper waters will have to be worked from a boat or raft.

Considerable difficulty is experienced at times with floating mats of the slimy green or blue-green alga. These masses of 1-celled

⁴ All but one of the cuts published herewith are copied from Britton & Brown's Illustrated Flora of North America. The figure of *Chara* is taken from the Text Book of Botany, by Strasburger, Noll, Schenk, and Schimper.



FIGURE 5.—Spiked water milfoil (*Myriophyllum spicatum*). Found in deep water, Newfoundland to Manitoba and the Northwest Territory, south to Florida, Iowa, Utah, and California. Commonly known as foxtail. Suited to southern ponds of high temperature, and, unlike most species, will thrive in comparatively soft waters. "Parrot feather" and introduced species of *Myriophyllum* will make better growth in sterile ground than the foxtail; otherwise the two have similar characteristics



FIGURE 6.—Fanwort (*Cabomba caroliniana*). Found in ponds and slow streams, southern Illinois to North Carolina, south to Florida and Texas. Characteristics similar to *Ceratophyllum*



FIGURE 7.—Hornwort (*Ceratophyllum demersum*). Found in ponds and slow streams throughout North America except extreme north. This plant is shallow-rooted, deriving most of its sustenance from the water. Will thrive in cold spring water



FIGURE 8.—*Chara fragilis*. A common form of chara. There are many varieties of this species and all are classed very high as food producers and oxygenators. Grows profusely in all limestone waters throughout the United States

microscopic plants harbor a rich fauna of the organisms consumed by the fish, but occasionally they may become so abundant that the periodical decay of the older plants may constitute an actual pollution of the water and make it uninhabitable for fish. Algæ are particularly obnoxious in connection with the draining of ponds or the handling of fish. It is almost impossible to prevent the smaller individuals from becoming entangled in the filaments. The most effective means of control is to haul the floating masses ashore by a seine or a drag of fine-mesh poultry netting. The various chemical methods of control—employing copper sulphate or other compounds—should never be applied in a fishpond.

SPECIES OF FISHES SUITABLE FOR POND CULTURE

SMALLMOUTH BLACK BASS (*Micropterus dolomieu*).—Indigenous to lakes, rivers, and smaller streams from Lake Champlain to Manitoba and south to North Carolina and Arkansas. It seeks by preference the clear cool waters of its range and in the Southern States is confined to the more rapid streams. The maximum weight is about 5 pounds and the average weight from 1 to 2 pounds. This species should be selected for cultivation only in ponds of 2 or more acres in area where the temperatures and other physical characteristics conform to those of its natural habitat. Rock bass and sunfish will live congenially with the smallmouth black bass and can be propagated successfully in the same ponds with them.

LARGEMOUTH BLACK BASS (*Micropterus salmoides*).—Known locally as straw bass, green bass, bayou bass, Oswego bass, trout, and chub. Its range is from Canada to the Gulf of Mexico and from the Atlantic coast to the Rocky Mountains. The species is prolific in congenial waters but reaches its greatest size in the warmer lakes and more sluggish streams of the South. Its maximum weight is authentically stated to be from 20 to 25 pounds, though in most localities it does not exceed a weight of 6 pounds, and the average is probably less than 3 pounds.

Because of their size and cannibalistic tendencies the two species of black bass should be selected only for ponds not less than 2 acres in area. The largemouth species is equally well adapted to cultivation in northern or southern climates, but its cultivation in the former should be restricted to waters attaining maximum temperatures. Crappie, sunfish, and warmouth bass are suitable species to introduce in waters with the largemouth bass.

The two black basses are frequently confounded, but they have contrasting marks of distinction, which vary somewhat with their environment. They may be reliably classified by the number of rows of scales on the cheek, the largemouth possessing 10 and the smallmouth 17 rows. The mouth of the former species extends back of the eye and that of the smallmouth even with the anterior margin of the eye.

CRAPPIE (*Pomoxis annularis*).—Commonly called bachelor, campbellite, new light, sac-a-lait, tinmouth, crapet, and chinquapin. Its range is from New York and Vermont westward through the Great

Lakes region and the Mississippi Valley to the Dakotas and south to Texas. It inhabits sluggish muddy water and reaches a length of 1 foot in its most southerly range. The crappie is an excellent pan fish and should be generally cultivated where conditions are favorable. It is an extremely delicate fish to handle, its protruding eyes being easily injured and frequently blinded when constantly exposed to direct sunlight in clear water. In ponds devoted primarily to the

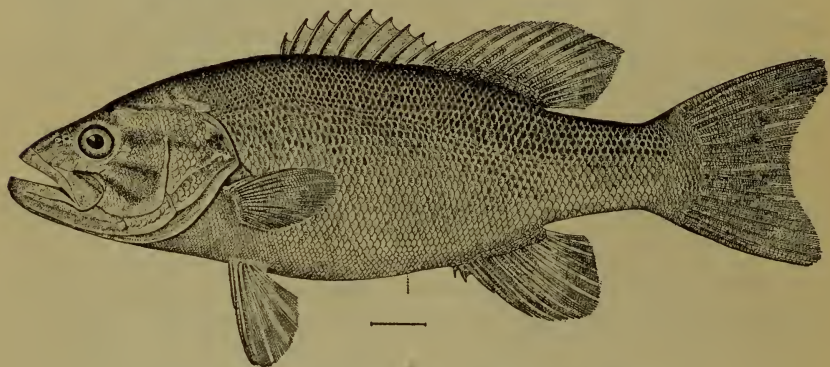


FIGURE 9.—Smallmouth black bass (*Micropterus dolomieu*)

propagation of crappie many fish-culturists introduce carp, suckers, or other bottom feeders, as the resulting turbid water seems to be a favorable condition for them. The natural habitat of the crappie suggests its suitability for ponds containing largemouth black bass or catfish, where the water supply is drawn from turbid streams or furnished by surface drainage.

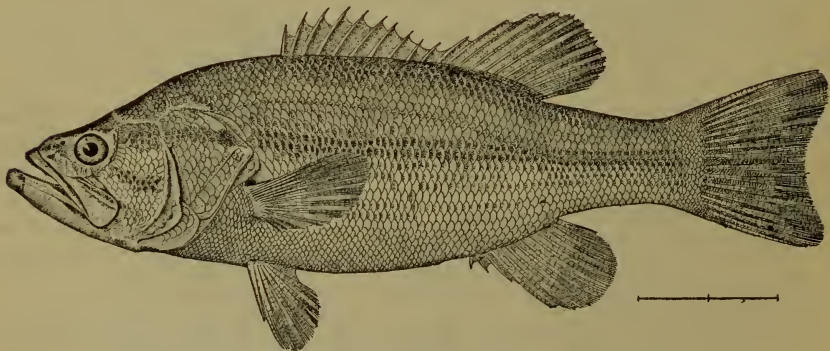


FIGURE 10.—Largemouth black bass (*Micropterus salmoides*)

CALICO BASS (*Pomoxis sparoides*).—Also known as strawberry bass, grass bass, and barfish. Is abundant in the Great Lakes region and the upper Mississippi Valley, with extreme range east to New Jersey and south to Texas. It very much resembles the crappie but is hardier in every respect and better adapted to pond culture. It may be distinguished from the crappie by the presence of 7 or 8 spines in the dorsal fin, where the crappie has but 5 or 6. It will thrive in

company with any of the pond species that are suited to relatively high temperatures.

ROCK BASS (*Ambloplites rupestris*).—Colloquially termed red-eye and goggle-eye. This species is found in lakes and streams from

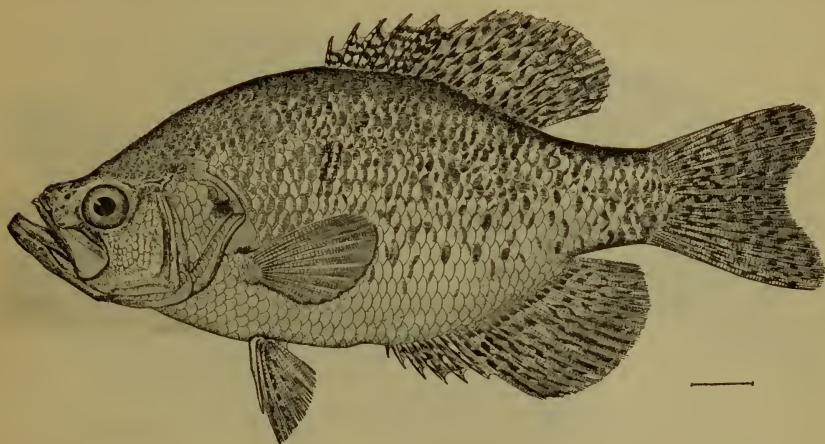


FIGURE 11.—Crappie (*Pomoxis annularis*)

New England to Manitoba and south to Louisiana and Texas, being particularly abundant in the cooler lakes and streams of the upper Mississippi Valley. It inhabits by choice only clear, cool waters and

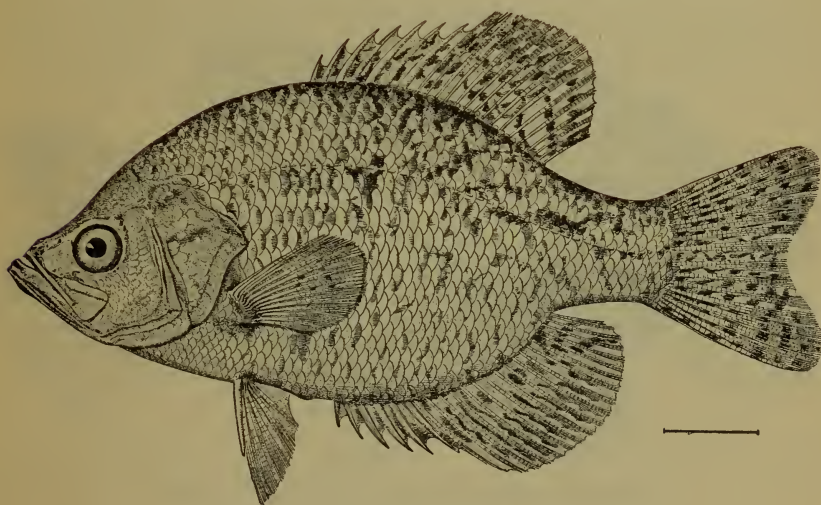


FIGURE 12.—Calico bass (*Pomoxis sparoides*)

is therefore less thrifty in its southern range. The rock bass has been known to attain a weight of $1\frac{1}{2}$ pounds and a length of 12 inches, but the average specimen probably does not exceed a weight of one-half pound or a length of 7 inches. Fish of this species are

well suited for introduction into spring-fed ponds with the small-mouth black bass.

WARMOUTH BASS (*Chænobryttus gulosus*).—Is often confused with the rock bass. It has very much the same range and similar general

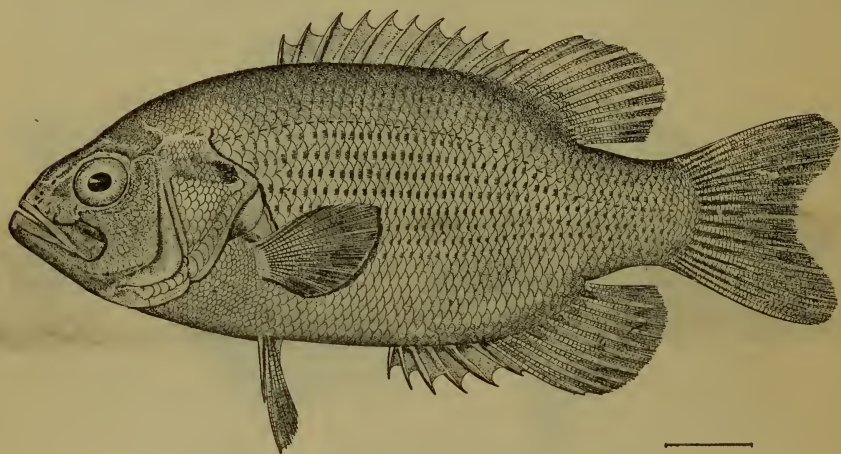


FIGURE 13.—Rock bass (*Ambloplites rupestris*)

characteristics but is better adapted to waters of a high temperature and is therefore most abundant in the South. The two species may be distinguished by the three oblique dark stripes radiating backward

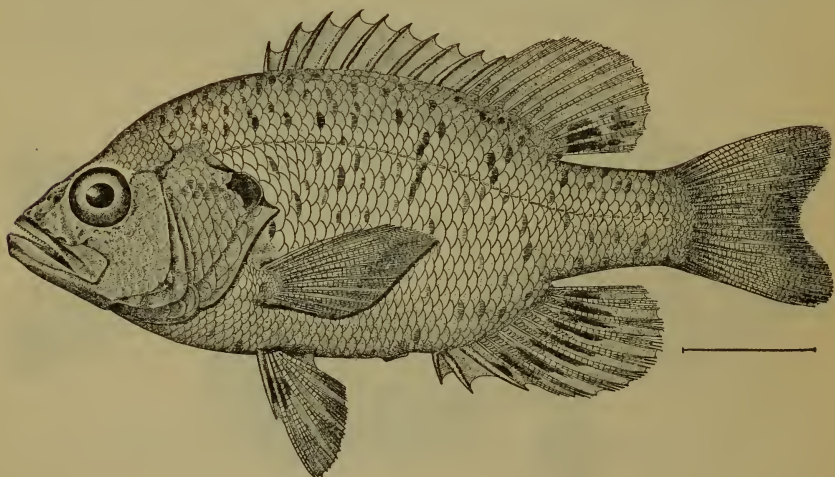


FIGURE 14.—Warmouth bass (*Chænobryttus gulosus*)

from the eye in the warmouth bass and by the rather indistinct vertical stripes on the body of the rock bass. The warmouth bass may be propagated in conjunction with the largemouth black bass or in small ponds with the crappie and sunfish.

SUNFISH (*Lepomis incisor*).—Locally termed bluegill, blue sunfish, copper-nosed bream, dollardee, and blue bream. Of the many species of sunfishes distributed throughout the United States east of the Rocky Mountains, this is the only one that can be recommended by the Bureau of Fisheries as worthy of artificial propagation, and it is

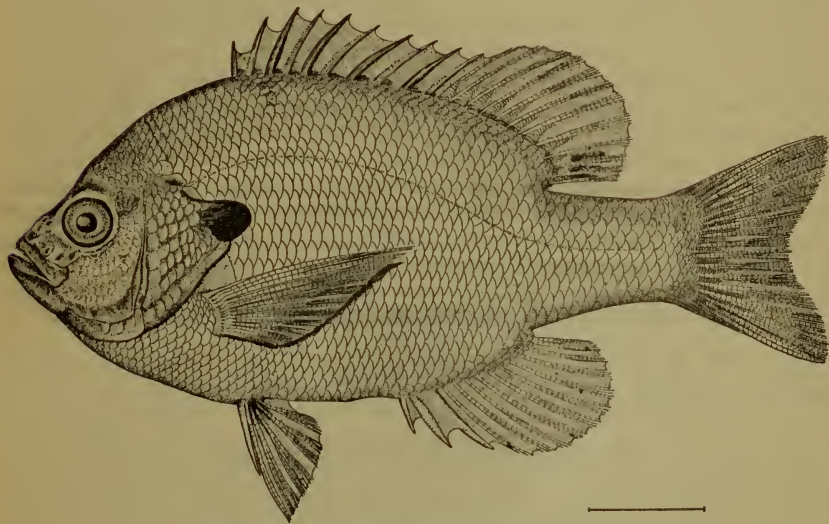


FIGURE 15.—Bluegill sunfish (*Lepomis incisor*)

believed to be the finest pondfish available for private culture. It is adapted to virtually all conditions, is prolific and of unsurpassed table qualities. The largest specimens will measure from 12 to 14

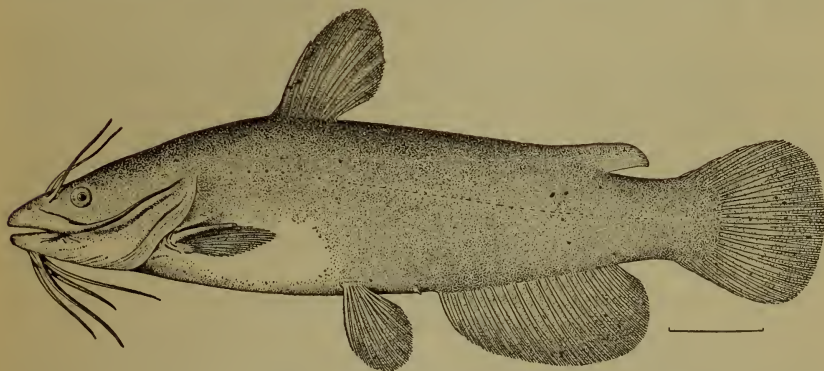


FIGURE 16.—Catfish or bullhead (*Ameiurus nebulosus*)

inches in length and attain a weight of nearly a pound. The bluegill may be propagated in connection with any of the other species listed above.

CATFISH (*Ameiurus nebulosus*).—Locally known as bullhead, horned pout, Schuylkill cat, small yellow cat, and the subspecies *Ameiurus nebulosus marmoratus* is known in the South as marble cat.

This is the only member of the catfish family that is adapted for rearing in private ponds. It is distinct from the genus *Ictalurus*, which embraces the larger catfishes—blue cat, channel cat, forked-tail cat, and spotted cat. Many attempts have been made to propagate these latter species, but extensive experience is requisite for success with these forms. They seem to require some element not found in still waters. The bullhead is abundant in all ponds, lakes, and sluggish streams of the eastern United States and the Mississippi Valley region. It adapts itself to widely varying conditions and demands less expensive preparation for its cultivation than any of the other fishes considered. The bullhead is the most easily domesticated of any of the pondfishes. Its appearance is formidable and repugnant to some, but when propagated in comparatively pure water it is very palatable. It may be cultivated in connection with any of the warm-water species referred to and is particularly suited to the changing conditions of drainage-fed ponds.

NATURAL AND ARTIFICIAL FISHPONDS

As with all forms of livestock, it is essential that brood fish be kept in a thrifty condition. Good food, proper shelter, ventilation, and exercise—familiar requirements to the farmer—have their equivalents in the food, physical characteristics of the pond, composition and aeration of the water, and the amount of space allotted to a given number of fish. Common sense, based upon observation of natural laws, will carry the fish-culturist a long way toward success.

All the fishes recommended for pond culture are naturally carnivorous, choosing live food through preference. Their predatory instinct in this respect can not be catered to exclusively where their culture is undertaken on an extensive scale, but the closer it is adhered to the better will be the results. It would be detrimental to the ultimate object in view to feed them live predacious species of minnows, for those that were not devoured would prey upon the young of the species being propagated, and eventually the minnow offspring would monopolize the vital resources of the water. The smaller minnows, with suckerlike mouths, may be advantageously liberated in the pond as food; for this purpose some fish-culturists utilize goldfish, which are herbivorous feeders and scavengers and which, in limited numbers, do not materially lessen the supply of natural food available for the game fishes. However, if the object is the production of a maximum quantity of food and game fish, goldfish have certain characteristics that make them undesirable in large numbers, and they may well be excluded from bass or crappie ponds. A separate pond a few square yards in area generally will produce an abundant supply of goldfish if it is desired to rear them for their ornamental value. Frogs, worms, and flying insects all contribute to the food supply of the brood fish; likewise the larger aquatic insects inhabiting the water. If not overstocked, therefore, the average pond may be managed so that it will furnish all the live food necessary for the adult fish. Where this is insufficient to maintain the stock properly, recourse may be had to stocking with forage fish or to pond fertilization.

USE OF FORAGE FISH IN BASS PONDS

Recent experiments conducted under the direction of Dr. H. S. Davis, using forage fish in ponds, have shown conclusively that the production of bass can be increased materially by stocking the ponds with minnows, on which the bass can feed. After reaching a length of 2 to 3 inches, bass, under natural conditions, feed largely on fish, and it has been found that they will make a much better growth if fish are included in the diet than when their food is confined to insects and Crustacea. Fingerling bass are naturally cannibalistic, and the greater part of the losses during the first summer usually are due to this habit. However, if there are plenty of minnows available, the tendency on the part of the fingerlings to devour each other is largely overcome, and the losses from this cause are reduced correspondingly.

The fish that so far have given best results for forage purposes are the golden shiner, *Notemigonus crysoleucas*, and the blackhead minnow, *Pimephales promelas*. On the whole, the golden shiner has been found to be more satisfactory than the blackhead minnow. The latter is a small, weak fish that is easily captured by the bass, and it is therefore difficult to maintain a stock of these fish in the ponds. Possibly both species could be used to advantage in the ordinary farm pond.

Not only do forage fish tend to prevent cannibalism, but they also materially increase the amount of food available for the bass. These minnows feed largely on algæ and small organisms that are not ordinarily eaten by bass and consequently make available a food resource that is largely lost if no forage fish are present.

The bluegill sunfish may also be used as a forage fish and have the added advantage that those not eaten by the bass are valuable for other purposes. However, for purely forage purposes bluegills are not as satisfactory as minnows, and where the production of bass is the primary consideration better results will be attained by the use of the latter.

Forage minnows may be liberated in the pond at any time, but when the pond is to be self-sustaining it is best to stock it with adult minnows early in the season before the fish begin to spawn. The golden shiner and blackhead minnow spawn at about the same time or a little later than the bass, but their spawning season extends over a much longer period. Consequently, if the pond is properly stocked with adult minnows there will be a supply of young of just the right size to serve as food for the fingerling bass.

FERTILIZATION OF PONDS

Doctor Davis's experiments have shown that when it is desired to obtain maximum production from a pond it will be advisable, in most cases, to fertilize it each season. The constant removal of fish from a pond without the addition of any fertilizer is like trying to grow crops without fertilization, and the results are much the same. As the amount of food available for the fish is dependent on the amount of plant life in the pond, it is evident that within certain limits we can increase the growth of fish by stimulating the growth of aquatic plants. Some recent experiments in carefully controlled ponds have

shown that properly fertilized ponds will produce from two to four times as much fish as unfertilized ponds.

A number of fertilizers have been used for the purpose, but it has not yet been determined which yield the best results. Well-rotted stable manure has been used successfully in some cases, but great care must be taken not to add too much of it at one time, as the dissolved oxygen in the water may become exhausted, with disastrous results to the fish. Probably the safest fertilizer for the purpose is a mixture of equal parts of dried sheep manure and superphosphate applied at the rate of 500 to 1,000 pounds per acre. This fertilizer should not all be added at one time, but small amounts should be applied at intervals of two to three weeks during the spring and early summer. It is best to scatter the fertilizer as evenly as possible in the shallow water along the margin of the pond.

DISEASES

There are no diseases of pondfishes that can be successfully combated by artificial means. A well-fed fish is usually a healthy fish, whereas thin specimens are wanting in resistance to their habitual parasites and can not readily recover from external injuries. If they are fed well on as nearly appropriate foods as can be secured and are carried in ponds of natural characteristics, sickness will be of rare occurrence.

STOCKING PONDS WITH BROOD FISH

The most successful and the speediest results in pond culture are attainable by the use of adult fish for the original brood stock. In most cases these can be secured from the public waters of the immediate locality during the open season prescribed by the State laws.

It is such a common failing to want something new and strange that many prospective fish-culturists endeavor to procure some species of fish foreign to their community with which to begin their operations. To illustrate some of the impractical ideas entertained, the Bureau of Fisheries is sometimes asked to furnish the species of trout indigenous to the Great Lakes for stocking southern waters or salt-water fish for introduction into ponds in the interior.

In general, it may be assumed that the species that is most prolific in the public waters of the region in question will be the likeliest to produce material results, and by procuring adult fish for breeders the pond in which they are placed should become stocked to its maximum capacity within a year. On the other hand, if State or Federal aid is relied upon, only a limited number of fingerling or, at best, yearling fish will be available for beginning operations, and it will require from two to three years for them to mature and stock the ponds through natural reproduction.

The wisest course, then, will be to choose some native species and to make a persistent effort to secure adult specimens. This can best be done in the fall months, when the fish will more quickly recover from slight injuries, which, during a period of high temperature, might develop into ugly sores and possibly kill them.

Fish hooked only in the mouth are in no way harmed as breeders, but the greatest precaution must be taken in holding them and in

transporting them to the pond. Loosening or rubbing off scales induces a fungus growth that eventually will spread over the body and result fatally.

As the fish are captured they may be placed in buckets or tubs, which may be darkened by throwing an old blanket or carpet over the top. In changing the water, which should be done as often as the fish seem to require it, care should be taken not to excite them. When the fish are to be held for several days before they can be transferred to the pond it is advisable to excavate a shallow basin at the margin of the lake or river where the collection is being made and arrange for a moderate flow of water from the main body through its entire length. A pool of running water 6 feet long, 3 feet wide, and from 12 to 18 inches deep will hold two or three dozen large fish with safety. Live boxes should not be used, as fish held in them will bruise themselves beyond recovery.

In conveying fish a considerable distance by rail or wagon, receptacles of such diameter that each specimen may lie at full length on the bottom should be provided. The depth of the water is a matter of less importance, but it should be kept at the proper temperature and well aerated. If necessary, ice may be used to maintain an even temperature corresponding to that from which the fish were taken; but if that be high and the distance to the pond great, it will be found easier to reduce the temperature to 65° and gradually raise it when nearing the destination to conform to that of the water in which the fish are to be liberated. During conveyance the water in the receptacles will be kept in motion and adequately aerated, but when standing still it must be aerated artificially by dipping out some water and pouring it back into the receptacle from a height.

The ordinary 10-gallon can or a special type of bucket developed by the bureau, and which holds about 6 gallons, is employed by the Bureau of Fisheries for the transportation of small fish, but if the fish are too long for their diameter nothing is better than wash boilers. Any clean receptacle may be used, but those mentioned are the most convenient to handle.

If the use of artificial food is not contemplated, the number of brood fish allotted to a pond must be apportioned to the natural food available for both the adults and the expected fry and fingerlings. Fifty of either species of black bass or 100 specimens of any of the smaller species are maximum numbers for an acre of water when the offspring is to remain in the brood pond. These numbers should produce a much larger number of fry than the waters can sustain until mature, but allowance will have to be made for losses through cannibalism and the ordinary vicissitudes of their environment. Promiscuous collections of fish invariably will run about equally as to sex, and the numbers recommended will therefore give 25 and 50 pairs, respectively.

There are no external markings by which the sex of pondfishes can be determined positively, but the female black bass usually presents a more mottled appearance than the male and her colors are brighter.

SPAWNING SEASON

Black bass will nest in the spring when the water temperature rises above 60° F. Ordinarily, 63° F. will bring about deposits of

eggs, but if the season is a backward one the fish may spawn at 58° F. On the other hand, an unusually advanced season may not bring results until the temperature exceeds 65° or 68° F.

Suitable temperatures for spawning prevail in the more southerly States as early as February; in the latitude of Tennessee, in March; in southern Illinois, during April; in Iowa, during May; and in northern Minnesota, in June. The spawning season extends over two or more weeks and is usually marked by two periods of intense activity following a rise in temperature after several days of abnormally cool weather. In the Southern States the nesting season is not so sharply defined, owing to the almost continuously favorable temperatures throughout the year, which cause rapid development of the ova. At the Texas station of the Bureau of Fisheries there regularly occurs a hatching period in February, one in April, and scattering hatches throughout the summer. The crappies, sunfishes, rock bass, and catfishes will spawn from one to two months later than the black bass in the same waters, and the sunfishes and rock bass will continue nesting to some extent until the approach of cold weather in the fall.

SPAWNING HABITS

Ordinarily, ponds will require no special preparation for the spawning season. Some of the species choose the roots of water plants on which to spawn, while others seek out gravel spots and find them, however much they may be hidden by deposits of mud. Catfish burrow into embankments and under rocks and logs, and it is well to provide substitutes for such shelters where this species is being propagated, for which purpose heavy planks weighted to the bottom of the pond will be suitable and will offer the least impediment to seining operations later on.

With the right material at hand the male will prepare the nest to his precise taste and after its completion will seek a partner. There are many ups and downs in the domestic life of fishes, especially in the case of such pugnacious species as the black basses. The battles of the males for favorite females are liable to cause injuries resulting in death; or, after being won, a consort may prove not sufficiently advanced in maturity, in which case the fish separate and the male continues his search for a more congenial mate.

Actual spawning will extend over several hours, the eggs being emitted and fertilized at varying intervals.

All the eggs carried by a female may not be ripe at one time, and the male will repeatedly seek new mates until the nest has been stocked to his satisfaction, driving each companion away when she ceases to perform the function for which she was obtained. The eggs are adhesive and attach themselves to gravel, roots, or other material on the beds. The male remains on the nest during the entire period of incubation, fanning the eggs clean of sediment with a gentle motion of his fins and watchfully guarding against the encroachment of other fishes on his domain. He is the personification of valor at this time, and all other creatures in the pond apparently have the greatest respect for him. Nothing but the loss or death of the eggs from low temperatures, heavy deposits of sediment, or other adverse conditions will cause him to abandon his nest. Not-

withstanding their ferocity, black bass will nest in close proximity to one another and attend to their respective parental duties in entire amity, whereas the approach of a strange fish will be resented.

Sunfish are decidedly gregarious during the spawning season and will locate their nests very close together. With them all is harmony, the sole thought of each appearing to be centered upon his own particular business.

The crappies spawn in comparatively deep water on isolated nests. Owing to their color, the depth of the water, and its usual turbidity, but few observations have been made of their peculiar characteristics at this period.

Rock bass and warmouth bass deposit their eggs on gravel beds of greatly varying diameters, and their spawning instincts are somewhat similar to those of the black bass, though in a less marked degree.

By reason of their intrepidity at the time, all of the species referred to appear to be very tame while guarding their nests, but this instinct should not be presumed upon by permitting unnecessary disturbances about the beds.

The incubation period of eggs of the various pondfishes ranges from a few days to two weeks or more, depending upon the mean water temperature. A drop below 55° F. is invariably fatal, while the percentage of hatch below 58° F. is greatly reduced.

Under uniformly favorable conditions healthy eggs will hatch without any loss to speak of, but the average hatch of domesticated stock is not over 50 per cent. This, however, is a sufficiently large percentage to make pondfish culture profitable.

CHARACTERISTICS OF THE YOUNG FISH—THEIR FOOD AND GROWTH

When first hatched the fry of most of these species are colorless and, because of their tendency to collect among the roots and in the crevices of the spawning beds, are difficult to find. They become darker in a few days, however, and are easily distinguished. In a short time they rise a few inches off the bed during the day and return to the bottom at night, increasing the distance each day until they eventually reach the surface. During all this time the parent fish has given them the same sedulous attention as when they were in the egg stage. Gradually the school enlarges in circumference to such an extent that he has difficulty in keeping his brood together. He crowds them into shoal water—their natural feeding ground—and patrols the shore in an effort to ward off enemies, but they finally separate into small bands, escape the vigilance of their guardian, and become free lances in the strife for survival.

The largemouth black bass and catfish fry school much longer than the other species mentioned; in fact, catfish fry retain this gregarious tendency throughout the first year, while young black bass remain together until 2 inches or more in length.

Young sunfish and catfish are easily taught to take artificial food when the natural food of the pond is insufficient for their nourishment. As with the adult fish, animal tissue is the most readily accepted and will produce the strongest growth, though cooked cereals

or vegetables will answer and are even relished by young catfish when given in the raw state.

The food should be scattered along the natural feeding grounds, starting with a small amount and increasing the quantity to what the fish will daily consume. Care should be taken to prevent the pollution of the pond through the decomposition of excess food.

The young basses and crappies can not be fed successfully and must depend entirely upon the insect life in the pond for their sustenance. For this reason no more young fish of these species should be carried in a pond than the natural food supply contained therein will support.

When such food is inadequate for the number of fish in a pond the only alternative is to provide additional ponds, to which a portion of the fry may be transferred for rearing. A public-spirited course would be to plant the surplus stock in neighboring public waters, taking care not to introduce them into streams and lakes that should be reserved to trout or salmon, as their presence would be detrimental to the latter species. Such a policy pursued by several fish-culturists in a given vicinity would maintain good public fishing without diminishing to any appreciable extent the quantity of edible fish in the waters under private control. Ordinarily, well-constructed ponds are capable of producing from two to ten times the number of fry that can be reared therein. The surplus is of some value as food for the stronger specimens but would be of much greater value if liberated in adjacent lakes or streams.

Some fish-culturists are feeding small fish by cultivating *Daphnia*—small aquatic crustaceans commonly known as water fleas. These multiply in great abundance in small, stagnant pools and ditches that are rich in organic matter or humus. These organisms can be raised artificially in pools, vats, or tubs that are fertilized with small quantities of rotted manure, prepared sheep manure, or rotting plants, such as lettuce leaves. Such a *Daphnia* pool is first fertilized, taking care to avoid the use of an excess of organic matter, which would tend to develop putrescent conditions. After several days the pool may be seeded with a stock of crustaceans taken from some natural pool where they abound. They multiply rapidly if the proper conditions are present, and in a few days a stock may be removed for introduction into the fishpond. They may be strained out of the pool by means of a bag or net of fine cloth, preferably silk. However, the successful use of these organisms for feeding fish requires considerable experimenting, and it should not be attempted without some knowledge of the fundamentals of aquatic biology involved.

CAPACITY OF A POND FOR THE PRODUCTION OF FISH

It is difficult to estimate the capacity of ponds for the various stages in the growth of fish. It depends for the most part upon the amount of appropriate food available. A 2-acre pond producing ten thousand 1-year-old black bass from 4 to 6 inches long would be a remarkably successful enterprise, and twenty thousand $1\frac{1}{2}$ to 2 inch yearling crappie or sunfish to an acre of water would be likewise notable. These numbers have been realized and in some instances exceeded, but the average results are doubtless much smaller.

The stock will be decreased through cannibalism at least 50 per cent by the end of the second year and the yearlings held over will consume a large percentage of the fry hatched during the second and succeeding years of operations. Enough should survive, however, to maintain the adult stock at the maximum number that the pond will support.

In waters of high temperature those species adapted to culture in ponds will attain maturity and reproduce at the age of 2 years. In cool waters reproduction may be delayed until the fourth year, or in case the species is very poorly adapted to the temperature conditions the fish may remain small, stunted specimens throughout life and never reproduce.

ENEMIES

There are many enemies of fish, especially of fry and fingerlings, against which the fish-culturist must wage continual warfare. The heaviest losses will result from cannibalism, and these will be gauged by the balance of the food and fish in the pond. Some species are more predacious than others. For this reason black basses, the scourge of restricted waters, are recommended only for large areas of the highest fertility. Such species as pike and pickerel should never be selected for culture in ponds, as they are the most piratical and devastating fishes inhabiting fresh waters.

It is necessary to guard closely against the inadvertent establishment in a pond of any undesirable species of fish or animal. Turtles and snakes will consume large numbers of fry and fingerlings in the course of a season and should be barred from the waters as strictly as possible. Kingfishers, herons, ducks, mudhens, and fish hawks soon discover a pond and prove most persistent poachers. Powder and shot is their most effective deterrent. If inroads on the stock are made by mink, they should be trapped in season—at a time when they will, at least in part, make reimbursement for their board. Muskrats, while not fish destroyers, work havoc with pond embankments and should be exterminated.

METHODS EMPLOYED BY THE BUREAU OF FISHERIES IN THE DISTRIBUTION OF FISH

The Bureau of Fisheries will undertake to furnish fish to individuals for stocking public and private waters. Blanks upon which to submit formal application will be supplied on request. Assignments of fish are made large enough to form the nucleus for a brood stock for a given area of water and are delivered at the applicant's railroad station free of charge. From the information given in these applications the bureau decides as to the suitability of the waters for the fish asked for and reserves the right to substitute other species if in its judgment the applicant's selection is ill chosen or it is impossible, with its limited facilities, to supply the species specified within a reasonable length of time.

None of the pondfishes recommended in the foregoing pages will be furnished by the bureau for stocking lakes or streams in Washington, Oregon, California, Idaho, Nevada, or the western portions of Wyoming or Montana, as it is believed their introduction into such

waters might prove detrimental to the important salmon and trout fisheries of the Pacific coast.

REMOVING FISH FROM PONDS

In removing fish from a pond at any time the same care should be exercised as in handling stock, due precaution being taken to reserve the best specimens for breeders and to retain a sufficient number for future reproduction. Their number and size must be left to the judgment of the proprietor of the pond, as it will vary greatly with the character of the water, size of the pond, climatic conditions, and geographical location.

In southern latitudes pondfishes commence nest building in March, while farther north, in Iowa and Illinois, reproduction does not occur until May or June. Young fish recently hatched are very tender and should not be molested for at least 30 days.

Care should be taken in removing adult fish from a pond, especially during the spring and summer months. In making the selection the larger fish should be preferred to the medium-sized ones, as the larger specimens are very destructive to the smaller fish. They are not as prolific as those of average weight and usually have attained their size through cannibalism.

If a few fish for table use are desired, and one has the time, they can probably best be taken with hook and line. A fyke net might be used under certain conditions, or a few might be taken in a trap constructed of light wooden framing covered with netting or galvanized wire cloth of about 1-inch-square mesh. The trap should have a cone-shaped entrance for the fish, and the interior should contain a few minnows in a wire cage, which are used as bait.

Where many fish are to be removed from a pond a seine should be employed. To use it to the greatest advantage about one-third of the water should be drawn off; this will cause the adult fish to congregate in the deeper waters, where they may be secured more readily. The water should be drawn off slowly in order to give the small fish a chance to follow it down.

Before drawing the pond the vegetation should be removed from the lower portion of it, where the seine is to be hauled. It may either be cut or raked out from the bank with a long-handled garden rake. Wading in the pond is to be avoided as it makes the water roily and leaves deep holes in the bottom, in which the young fish are likely to be caught.

In lowering the water vegetation of a rank and dense growth is very apt to settle down and smother the young fish. It should be moved as soon as observed, but cat's-tail and other plants having stems of sufficient strength to support them in an upright position need not be removed unless this is necessary in order to haul the seine.

In many instances it might not be necessary to draw off the water if the vegetation were removed from a portion of the pond and the fish fed regularly in the cleared space, for with a seine could be passed around them and a large number secured.

It is inadvisable to draw a pond during the warm summer months unless one has the supply of water available to refill it at once.

Better results are attained by drawing off the water in the cool fall months, but even then one should be sure of being able to refill the pond before freezing weather. For this reason it is believed that seining with a large net in the clearing where the fish have been accustomed to feed would give the best results.

When the proper amount of water has been drawn off the seine should be laid out from a boat and hauled toward the bank at the deeper end of the pond. In case the deepest place is near the middle of the pond, it will be necessary to work the seine around the fish and haul it toward the nearest bank.

Should more fish be removed from the pond than are desired for immediate use, the surplus can be placed in a floating live box anchored near the outlet or where the water is deep. This box should be made of wooden slats placed far enough apart to permit a free circulation of water and yet retain the fish. The slats should be nailed to a small frame of 2 by 2 inch material, forming a box 16 feet long, 4 feet wide, and 3 feet deep and provided with a hinged cover.

If preferred, a small inclosure in the pond, fenced with galvanized wire, might be provided for holding surplus fish, removing them when required with a large hand dip net or a small seine. The advantage of the inclosure over the live box is that it will not crowd the fish, and they can thus be held under more natural conditions.

PRODUCTION OF FISH FOR STOCKING PURPOSES

While the foregoing information is largely applicable to the production of fish, either for food or for transplanting to fishing waters, the two purposes are somewhat different, and some variation in procedure is necessary. In one case the object is to produce the greatest possible poundage of adult edible fish, while in the other the aim is to provide the greatest possible number of individuals 2 or 3 inches or more in length. To accomplish the latter purpose it is desirable to assure a minimum of cannibalism by providing an abundant food supply, usually correlated with an extensive water area, in which the fish can forage. Above all, it is essential to segregate the various ages so that any one pond will contain fish of the same season's hatch only; although, if it is impossible to remove the parent fish, they will not prey upon their progeny to the same extent as would the yearlings.

Spawning ponds therefore should be drawn down yearly and the season's output planted in open waters or transferred to other ponds for rearing. In the case of bass it is desirable, if possible, either to remove the adult fish after the schools of fry have scattered or, preferably, to remove at least half of the young fish to another rearing pond. It is frequently the case that 50 per cent or more of the bass fry may be removed from a spawning pond, and virtually as many 2-inch or 3-inch fingerlings will be obtained from the original pond as would be the case if none had been removed. The quantity of fingerlings secured from the transferred stock thus constitutes an additional return. The fry may be captured before the schools have scattered entirely by means of a bobbinet seine 10 or 12 feet long or a rectangular dip net of the same material operated

from the shore. At the bureau's hatcheries fry are captured by circular wire fry retainers or by special fry traps, construction details of which will be furnished on application.

It is obvious from the foregoing that many ponds that are satisfactory for raising of a limited number of adult fish for food will be useless for raising fish for stocking purposes. If conditions are such that virtually 100 per cent of each season's hatch of fingerlings can not be removed, the pond will be lacking in one of the primary essentials for this purpose. Many mill ponds, ice ponds, and similar ponds, which may be very productive of fish, will be of no value as nursery ponds because the crop can not be harvested. The ideal plan for a project to be devoted to the rearing of fish for angling is to have a series of several ponds, only one of which will be stocked with breeders, the rest serving as nurseries. In this respect a practice should be followed that may not be applicable to farm fishponds that are kept constantly stocked. If possible, ponds should be left dry for several months of the year, preferably during the winter. This sweetens the soil, tends to check the development of obnoxious vegetation or diseases, and permits cultivation of the pond bottom.

In stocking a pond for fry production only a small number of breeders will suffice. Not more than 40 adult bass should be allotted to an acre of water, and under favorable conditions half this number will produce all the young the pond will support. There is no advantage in hatching a surplus of fry to compete among themselves for food with a resultant production of underfed fingerlings of little value for stocking.

Any pond that meets the above requirements will, of course, serve equally well as a rearing pond for the retention of young fish received from Federal or State hatcheries. While the confinement of any large number of young bass in a small pond undoubtedly augments the losses due to cannibalism, the protection from other enemies generally prevalent in open waters will, to a large extent, offset this drawback. Under intensive methods, with attention to pond fertilization, artificial feeding, etc., an acre of pond may be made to produce 10,000 or more 2-inch to 4-inch bass at an age of 5 months. Ordinarily, however, a production of one-half or two-thirds of this number may be considered highly satisfactory. In stocking a pond with fry a loss of from 50 to 65 per cent may be expected during the first six months. Hatches of 20,000 or 30,000 fry per acre are not unusual, however, and nature has thus provided for this early mortality.

A number of sportsmen's organizations have provided their own bass hatching and rearing establishments along these lines with great success. Some have utilized ponds in city parks, others have constructed entirely new ponds, while others have altered existing natural ponds to serve their purposes. In Michigan the State authorities have furthered such work by creating an official position, the duties of which are the development and supervision of such projects. Wherever it is intended to carry on such operations on any but a limited scale the whole project should be reviewed by a competent fish-culturist for the purpose of determining its feasibility and the most efficient scheme of development.

